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Up, Down, Turn Around: Assisted Wayfinding Involving Level Changes

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Abstract. Both maps and verbal descriptions have been shown to be an effective wayfinding assistance. However, most studies investigating these aids have been performed in two-dimensional spaces that ignore level changes. It seems less clear that both types of assistance work equally well in settings that involve going up some stairs or taking an elevator. In this paper, we present a study that had participants follow a route in a multi-level setting involving several level changes while being assisted by either a textual description or a sketch map. Results indicate that both types of assistance are effective and that the few differences in performance that we discovered can be attributed to differences in the employed wayfinding strategies rather than differences in the assistance types. Our findings have implications for the design of (mobile) assistance services that aim at using graphical instructions for guiding users seamlessly through indoor and outdoor environments.

Keywords: route following, description vs. depiction, sketch map, level change

1 Introduction

Wayfinding is an everyday activity. It reflects our ability to plan a path to distal destinations and to reach those [1]. For routes that we follow regularly wayfinding becomes a simple, almost subconscious task, but if we plan to travel to places for the first time we usually require some kind of external support. Typically, such wayfinding assistance comes in the form of a verbal description or a graphical depiction, or a combination of these.

People can successfully navigate with both forms (e.g., [2, 3]). However, for the most part this has been established for two-dimensional space, usually involving movement throughout an urban setting. When the routes to follow include level changes, for example, going up a staircase or taking an elevator, it is not as clear whether all forms of providing route directions are equally suited. Route following involves performing a sequence of navigation actions—essentially turning at decision points and then moving to the next. Verbal descriptions by necessity need to linearize the information they convey [4]. Thus, they seem well suited

to communicate the sequence of navigation actions independent of whether the space to navigate in is two- or three-dimensional. Maps, on the other hand, are two-dimensional per the medium used. It seems less clear how well it is possible to clearly communicate level changes using (sketch) maps. For example, this may become an issue in the pursuit of designing navigation services or other location-based services that offer seamless assistance between indoor and outdoor settings (e.g., [5, 6]).

In this paper, we report on a study that tested wayfinding performance in a setting that involves level changes when participants are assisted by either a textual description or a sketch map. While there are some performance differences, results indicate that both forms of assistance work well. The decisions taken in designing the sketch map seem sensible, which has implications in particular for designing effective graphical aids for multilevel (indoor) wayfinding assistance.

2 Wayfinding and Wayfinding Assistance in Multi-level Settings

As stated in the introduction, both maps and verbal descriptions can successfully convey the information necessary to reach a destination. For example, Meilinger [2] found that people mentally seem to translate route maps into propositional instructions on how to find the way. And Tversky and Lee [7] claimed that both forms have the same underlying semantics and, thus, can be seen as (nearly) equivalent in communicating route information (but see [8] for some counterarguments).

In most of the research on wayfinding assistance level changes are ignored. Largely, this research looks at how people perform with verbal descriptions or maps while navigating in an (essentially) two-dimensional space. However, there are indications that being assisted in multi-level (vertical) spaces may result in different effects. In studies performed in the Paris subway, Fontaine [9] showed that in underground (subway) environments there are differences in how people produce route directions compared to directions on (outdoor) ground level. Depending on the kind of external aid participants received, she also found differences in route following and acquired spatial knowledge [10]; different graphical aids differ in the effectiveness for different people and situations. Münzer and Stahl [11, 12] demonstrated that in a complex university building participants using animated virtual walks as wayfinding assistance made fewer wayfinding errors than those using static allocentric or egocentric views.

In principle, people seem to be able to integrate spatial knowledge across different vertical levels [13]. Different factors may make this easier or harder [14]. For example, Weisman [15] identified visual access, architectural differentiation, signage, and floorplan configuration to contribute to the ease (or difficulty) of wayfinding situations. Similarly, several others have studied the effects of an environment's spatial layout on wayfinding (e.g., [16–18]). In particular, Soeda et al. [19] found that level changes, i.e., moving vertically, often disrupt orientation. Regaining orientation is then hindered if the layout between the two floors differs

widely or if there is a misalignment of reference systems between floors [17]. Ishikawa and Yamazaki [20] demonstrated this disorientation in a study where participants had to point towards a (ground-level) destination after exiting a subway station. They found that photographs allow participants faster and more reliable reorientation than maps.

Similarly, the research presented in this paper focuses on the effect of different external aids—namely textual description vs. sketch map—on people's wayfinding success in multilevel settings.

3 An Empirical Study Comparing the Effectiveness of Textual Descriptions and Sketch Maps in Multi-level Settings

Given the research just discussed, we are interested in seeing whether maps and textual descriptions perform comparably well in wayfinding situations that involve level changes. To this end, we set up an experimental study, which has participants follow a route that involves both transitions from indoor to outdoor (and back) and multiple level changes. In their route following, they are assisted either by a sketch map or a textual description (text for short). We hypothesize that using a text in this kind of setting is easier than a map, as textual instructions are generally more straightforward to translate into wayfinding actions and, in particular, level changes are harder to communicate (well) using a map. Thus, we expect participants using the text to reach the destination faster and with fewer errors.

We also have participants rate the difficulty of the wayfinding task before and after actually performing the task. We included this test to detect possible preferences of the participants for either the map or the text and as an indication of subjective difficulty assessments. While we expect to see clear changes to occur between the two ratings, it is difficult to predict in which direction. There are good reasons to assume that afterwards the task appears easier than before (e.g., because 'the unknown' is always hard to judge), but likewise also the opposite may be the case (e.g., because both descriptions are rather short and, thus, the route may appear simpler than it actually is).

3.1 Participants

32 students (16 men, 16 women) of the University of Zurich participated in the study. Their age ranged from 19 to 37 (μ=24.9 years). Since the study was performed on the university campus, all participants have been in the general area of the study, but none ever took the study route, though parts of the route may have been known to some participants.

3.2 Study Area and Material

The study area is at the University of Zurich in Switzerland, namely at the Irchel Campus. The route chosen for the study comprises of nine direction changes and

two changes of level (see Figure 2a). The destination point cannot be seen from the starting point and vice versa. The path leads mainly through buildings, but at one point the participants had to go outside through a door and later back in again. Figure 1 shows some impressions of the study route.

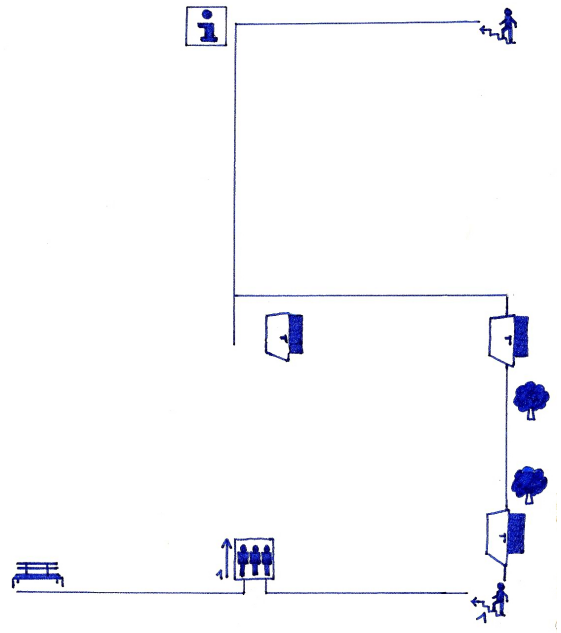
a) b)

Fig. 1. Example scenes from the study route: a) The first glass door the participants have to pass through to get outside; b) the second level change occurring along the route.

A pre-test led to several adaptations to both the initially produced map and text in order to reduce confusion. The map (Figure 2a) and text (Figure 2b) contain the same elements. For both forms of assistance, design employs a route perspective. The text only uses 'left' and 'right' direction statements and references to landmarks. There are no indications of distance. Likewise, the map does not provide any information on (relative) distances; all path segments on the map have the same length. Turns are depicted using prototypical 90 degrees angles. In order to visualize landmarks, either well-known icons are used, such as the 'i' (information) sign, or icons that we believe are pictographic representations of the real-world object referred to, such as the open door or the tree icons [21] as can be seen in Figure 2a. Level changes are indicated by arrows—in the study always up—annotated by the number of floors to pass (here always '1'). These arrows either come in the shape of stairs or are placed next to an elevator icon. While distances are ignored, directions between elements are meaningful in the map, for example, the elevator is placed to the right of the route segment because it is actually located to the right when walking the route.

3.3 Experiment Design and Procedure

The experiment was conducted in German. The participants were divided into two groups of 16 participants each, with a balanced proportion of women and men. One group completed the task with the map, the other with the text. At the beginning of the experiment, each participant filled out a questionnaire with some demographic data. Afterwards each participant received their respective



a)

Geh die Treppe hoch. Geh bei der Information links. Geh bei der nächsten Möglichkeit links. Geh durch die zweite Tür auf der rechten Seite. Geh rechts an den zwei Bäumen vorbei. Geh durch die Tür. Geh die Treppe ein Stockwerk hoch. Geh links. Geh bis zum Lift auf der rechten Seite. Geh mit dem Lift ein Stockwerk hoch. Geh rechts zur Sitzbank.

Go upstairs. Turn left at the information desk. Turn left at the next possible option. Go through the second door on the right hand side. Pass to your right the two trees. Go through the door. Go upstairs to the next floor. Turn left. Go to the elevator to your right. Use the elevator to get one level up. Turn right and go to the bench.

b)

Fig. 2. The map (a) and textual description (b) used as material in the study. Participants received the German text; the English translation is provided for the reader's convenience.

wayfinding assistance (map or text), printed on a DIN A5 page. Participants then had 30 seconds to study the material, after which they had to hand it back and then had to rate how difficult they expected the wayfinding task to be on a Likert scale from 1 (very easy) to 5 (very difficult).

Participants were then led to the starting point of the route. They were instructed to find the way described on the map or the text, respectively, and to clearly communicate when they believed they had reached the destination (the bench). They were also told that they would be followed by the experimenter, but would not receive any help from them, nor were they allowed to ask anybody else for assistance. They were given back the (same) assistance material they studied previously and started the wayfinding process taking the material with them, i.e., they were able to refer to either the map or text while following the study route. Participants were followed by one of the experimenters who did not intervene, but only recorded the time participants took and their behavior.

In particular, we recorded any errors, stops or hesitations along the way. We defined an error to be five steps in the wrong direction—any follow-up errors were ignored. During a stop, participants ceased moving forward and stood still to inspect the text or map, whereas during hesitation they only slowed down and looked at the assistance material while still moving. These variables have been previously used by Daniel et al. [22] in their studies.

Once participants indicated that they had reached the destination, the timer was stopped and they were again asked to rate the difficulty of finding their way on the same Likert scale as before. This rating was recorded, and participants were debriefed by receiving a chocolate bar as a small token of appreciation for participating in the study.

4 Results

In this section we will report on the results of the wayfinding study. In particular, we will check our hypotheses regarding potential differences in performance when assisted by text or map, respectively, and the changes in difficulty rating. The statistical evaluation is detailed below. All tests are performed against a significance level of 0.05.

A total of nine people (three using the text; six using the map) misjudged having reached the destination and stated at a wrong place that they finished route following. Still, all of these nine reached the correct floor, therefore, we included them in the analysis of error, hesitation and stop—except for finishing at the wrong place they did not make any additional errors. However, in the analysis of time they are excluded as their routes (route lengths) differ from the intended route.

4.1 Correlation of Error, Stop, and Hesitation with Time

To begin the analysis, we will check whether and how the behavioral variables error, stop, and hesitation correlate with time. We will first look at the partici-

pants overall, and then divide them according to the type of assistance (map or text) used.

Correlations without Differentiation of Assistance Type First, in order to calculate a correlation, all variables including time were tested for normal distribution using the One-Sample Kolmogorov-Smirnov test. Time, stop, and error are normally distributed, however hesitation is not. Accordingly, a Pearson-correlation was performed for the pairs time-stop and time-error. We did not find any significant effect for stop ($p = 0.397$) or error ($p = 0.083$). For the pair time-hesitation the Spearman-correlation was used; again there is no significant effect ($p = 0.595$). That is, there seems to be no correlation between time and any of the behavioral variables when looking at the overall participants.

Correlations with Differentiation of Assistance Type Next, we looked at the two conditions (map or text) individually. Again we tested for normal distribution. All variables except for error in the map condition are normally distributed. The Pearson-correlation showed no statistical relationship for the pairs time-stop and time-hesitation for either of the description types. The same holds for time-error in the text condition. However, in the map condition, there is a significant posititve correlation for the pair time-error ($r = 0.722$; $p = 0.018$). Table 1 summarizes these results.

Table 1. Significance of correlations at 0.05 level for the different study conditions.

	Correlation Significance		
	time and stop	time and hesitation	time and error
map	0.879	0.226	0.018
text	0.902	0.251	0.367

To sum up, again there are no statistically relevant correlations between the behavioral variables and time, except for the errors that occurred in the map condition.

4.2 Difference of Description Type

The main goal of this study was to establish whether there are any performance differences between using a textual description or a sketch map as assistance when finding the way in a multi-level setting. In the following, we will test for this by comparing the behavioral variables between the two experiment conditions.

Hesitation A t-test (without equal variances) shows no statistically significant difference between the number of hesitations when using the text or the map ($p = 0.763$).

Stop For the number of stops, a t-test with equal variances reveals a significance of $p = 0.108$, so no significant difference can be found between using the text and using the map.

Error The number of errors are not normally distributed. Therefore, a Mann-Whitney rank-sum test was used to establish significant differences. But, again, none were found ($p = 0.616$).

Time Finally, we tested for any differences between the time it took participants to finish the route either with assistance by the text or by the map. A t-test with equal variances with all participants included (also those that named the wrong destination) shows no significant differences ($p = 0.215$). Still, when looking at the mean values (μ_{map} =327.47s; μ_{text} =288.35s), there is a difference of nearly 40 seconds, which seems relevant. Therefore, the nine participants who did not reach the correct destination were excluded from analysis and another t-test was performed. This test shows a significant difference of $p = 0.011$. Participants using the map ($\mu_{map_{excluded}} = 362.5s$) have been significantly slower than those using the text ($\mu_{text_{excluded}} = 269.8s$).

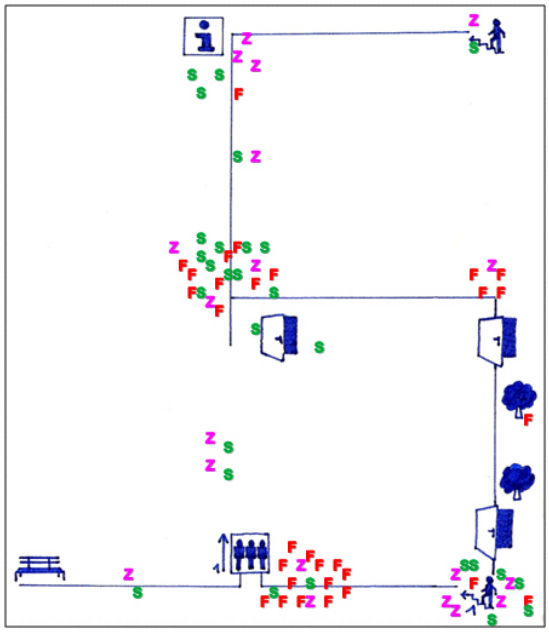
To sum up, there are no significant differences in the behavioral variables between the two test conditions map and text, but participants are slower when using the map than when using the text. Reasons for these differences will be discussed in Section 5.

4.3 Visualization of Behavioral Variables

In order to examine where in space errors, stops, and hesitations occurred, we marked them on the respective assistance types, i.e., text and map (Figure 3). In this figure, F, S, and Z stand for error ('Fehler'), stop ('Stopp'), and hesitation ('Zögern'), respectively. Clear clusters emerge in both assistance types. Interestingly, these are located at the same corresponding locations in the real world, i.e., these clusters do not seem to depend on the assistance types, but rather on the real-world situation. One cluster is located at the first door to get from within the building to the outside. A second cluster of recorded behavior is at the elevator. Thus, these two locations can be seen as potentially difficult spots where errors are likely to occur, which will be further discussed in Section 5. In the map condition there is a third cluster of stops and hesitations around the staircase that leads up after having entered the building again.

4.4 Changes in the Difficulty Rating

As stated in Section 3, we expect changes in the assessment of task difficulty to occur from rating it before following the route to when having finished the route following task. Rating was done using a 5-point Likert scale (1=very easy; 5=very difficult). The changes reported in the following are calculated simply by the difference between the rating after route following and before route following.



a)

Geh die Treppe hoch.	Go upstairs.
Geh bei der Information links.	Turn left at the information desk.
Geh bei der nächsten Möglichkeit links.	Turn left at the next possible option.
Geh durch die zweite Tür auf der rechten Seite.	Go through the second door on the right hand side.
Geh rechts an den zwei Bäumen vorbei.	Pass to your right the two trees.
Geh durch die Tür.	Go through the door.
Geh die Treppe ein Stockwerk hoch.	Go upstairs to the next floor.
Geh links.	Turn left.
Geh bis zum Lift auf der rechten Seite.	Go to the elevator to your right.
Geh mit dem Lift ein Stockwerk hoch.	Use the elevator to get one level up.
Geh rechts zur Sitzbank.	Turn right and go to the bench.

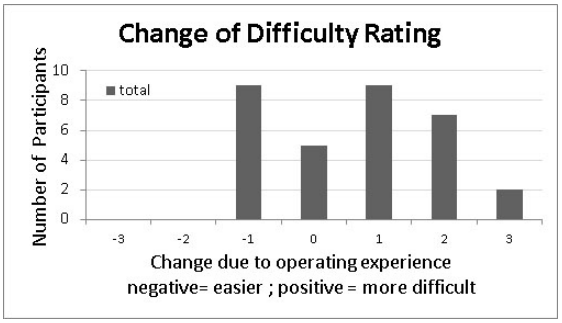
b)

Fig. 3. Visualization of where errors, stops, and hesitations occurred along the way; a) when using the map; b) when using the textual description [F: error (‘Fehler’), S: stop, Z: hesitation (‘Zögern’)].

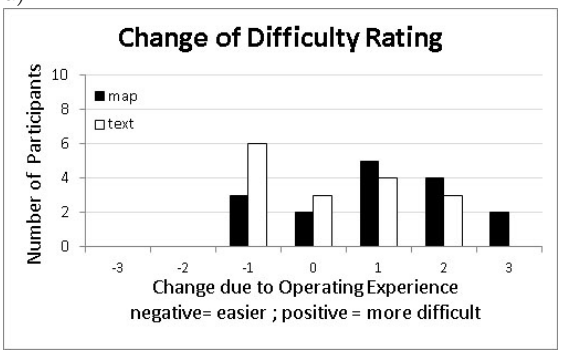
Accordingly, negative values state that the task was rated easier after having performed the task compared to before the task. Positive values indicate that participants underestimated the difficulty prior to the task and had to correct this after the task.

Figure 4 illustrates these changes of rating. In Figure 4a) all 32 rating changes are included, independent of assistance type. Nine participants rated the task as easier after the task, five people rated the task as equally difficult before and after route following. 18 participants stated that they underestimated the difficulty and rated the task as more difficult in their second rating.

Figure 4b) illustrates the change of difficulty rating differentiated by assistance type. Eleven out of the 18 participants that underestimated the difficulty used the map and only seven used the text. In contrast, six out of nine subjects that overestimated the difficulty used the text. No clear difference between assistance type can be found for the neutral group. Interestingly, when participants changed their difficulty rating, they only used a single point (step) if they found the task easier than previously thought, but used a broader range of ratings in case they felt it to be more difficult than initially thought.



a)



b)

Fig. 4. Changes in difficulty rating; a) overall; b) separated between map and text.

Overall, participants rather found the wayfinding task more difficult than initially thought, and rather not easier. This is particularly true for participants using the sketch map as wayfinding assistance.

5 Discussion

The results of our study show that participants can successfully find their way in a multi-level setting using both types of assistance—sketch map or textual description. Generally, we did not find any significant differences in the behavioral variables error, stop, and hesitation between the two conditions. However, on average map users take significantly longer to finish the route following task than participants using the text. Also, the only significant correlation between any behavioral variable and time was found for the time-error pair for the map users. Consequently, our first hypothesis, namely that participants with the text are faster and make fewer errors, only holds partially.

Even if there is a positive correlation between errors and time in the map condition, this does not mean that map users made more errors than those assisted by the text. Rather, the reasons for taking longer reside within the wayfinding strategies that participants employed. Map users tended to less quickly turn around when they noticed that they had gone wrong. The medium map with its two-dimensional layout character offers greater potential to get back on the correct track after an error, even if the particular map used in this study really only showed the route to take without any further overview information. For example, in both conditions several participants after turning left at the information desk moved straight ahead instead of turning left again. While participants using the text eventually turned around again, map users were able to recover and still reach the second staircase, albeit on a different route, which took longer than the original one. Using a map allows for different error recovery strategies than using a text, which do not make a difference in the number of errors, but may make a difference in the time it takes to finish the task.

Our second hypothesis—people change their mind regarding the perceived task difficulty after actually having performed the task—overall holds true. Typically, the task was seen to be harder than expected in retrospect. In particular, when using the map, finding the route seemed easier initially than it was in the end, whereas for the text differences in rating are more even (some perceived it as harder, some are easier, some as equally difficult). The map seemed to better allow for gaining an idea of what to expect compared to the text, even if this mental image of the route possibly turned out to be inaccurate—therefore the change in rating to be more difficult. While we have not tested for this (e.g., through debriefing interviews), one reason may be that all distances are depicted as equal on the map, which would result in a heavily distorted mental image of the actual route.

We were also particularly interested to see whether sketch maps are suitable tools to instruct wayfinders in multi-level settings. Overall, we can conclude that they work well. All participants were able to understand the used icons

and in particular performed the correct level changes. Still, as can be seen in Figure 3, both text and map are not without problems. Despite multiple pretests there were still confusing situations in following the route, which showed up in the behavioral data (errors, stops, hesitations). One of these issues occurred through an omission of an instruction. When coming up the stairs towards the information desk, participants actually had to turn left after the stairs to get there. The desk is clearly visible from the top of the stairs, so we omitted this instruction, which confused several participants. They clearly expected having received complete step-by-step instructions.

A second confusing situation occurred when needing to pass through the door after the information desk. The textual description states to pass through the second door ('Gehe durch die zweite Tür'). However, in the actual environment there are double-doors located there, thus, the textual instruction may be interpreted differently to the situation depicted on the map. A third issue proved to be the elevators. Both the text and the map (through positioning the elevator icon to the right of the route) clearly state to take the 'elevator on your right'. Close to where the relevant elevator is located there is a second elevator to the left of the route. Several participants took this elevator to the left, which subsequently took them off the route because when exiting the elevator they turned right (as instructed) but would have had to turn left to compensate for taking the wrong elevator. Again, map users had a better chance to compensate for this error, but overall–while technically correctly instructed–participants did not pay enough attention to the instructions at this location. It seems that more care needs to be taken to design instructions that point out and resolve such ambiguities.

Finally, our experiment was executed in a particular type of environment, namely university buildings. These buildings usually are structured along corridors–maybe to slightly lesser extent than office buildings–and these corridors offer clear affordances. Once the correct corridor is selected, there is not much choice than to follow it until it meets some other corridors or open space. In other words, corridors do not offer many opportunities for going wrong once inside them (of course it is always possible to choose a wrong corridor). Similar experiments to the one presented in this paper should be performed in other, more open space environments, such as train stations or exhibition centers, to come to more general conclusions regarding the performance of sketch maps and the use of icons in multi-level wayfinding support.

6 Conclusions

Both maps and verbal descriptions have been shown to be effective wayfinding aids in the past. However, most of those studies were performed in two-dimensional spaces where level changes (e.g., going up stairs or taking an elevator) did not occur. Some previous research indicates that there may be differences between both types of assistance in such three-dimensional settings.

In this paper, we presented a study that tested for such differences by having participants follow a route that involves several level changes while being assisted by either a textual description or a sketch map. The sketch map was designed in a way that it indicates direction changes, but not distances between decision points. Level changes as well as landmarks along the route are depicted using standard icons or pictographic representations. Results of the study show that both types of assistance work (almost) identically well. In particular, participants using the sketch maps had no difficulty in correctly executing level changes. Differences between maps and texts can be attributed to differences in wayfinding strategies, not to differences in their effectiveness.

Thus, we conclude that sketch maps and the use of stylized icons seem a suitable way of assisting people when finding their way in multi-level three-dimensional spaces. Among others, our findings have implications for the design of (mobile) assistance systems that universally guide users through both indoor and outdoor spaces (e.g. [5]).

The study presented in this paper should be seen as a first step towards using sketch maps and icon-based instructions in such scenarios. More studies are needed to systematically test their performance and the usefulness of the icons in guiding people through different settings. In particular, gender and individual differences should be investigated in follow-up studies. In our study, we balanced for gender in the different conditions, but did not find any significant differences between the genders—neither for the overall group nor in the individual conditions. A larger participant group may provide more robust results to discard such gender differences.

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